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ABSTRACT

The purpose of this report is to present and prioritize the major environmental, safety, and social/institutional issues associated with the further development of Solar Total Energy Systems (STES). Solar total energy systems represent a specific application of the Federally-funded solar technologies. To provide a background for this analysis, the basic concepts of STES are reviewed, as are their resource requirements. The potential effects of these systems on the full range of environmental concerns are then discussed in terms of both their relative significance and possible solutions. Although the development of STES will contribute to environmental problems common to any construction project or energy producing technology, only those impacts unique to the solar portion of the technology are discussed in depth. Finally, an environmental work plan is presented, listing research and development proposals and a NEPA work plan which might help clarify and/or alleviate specific environmental problems. (Author/MR)

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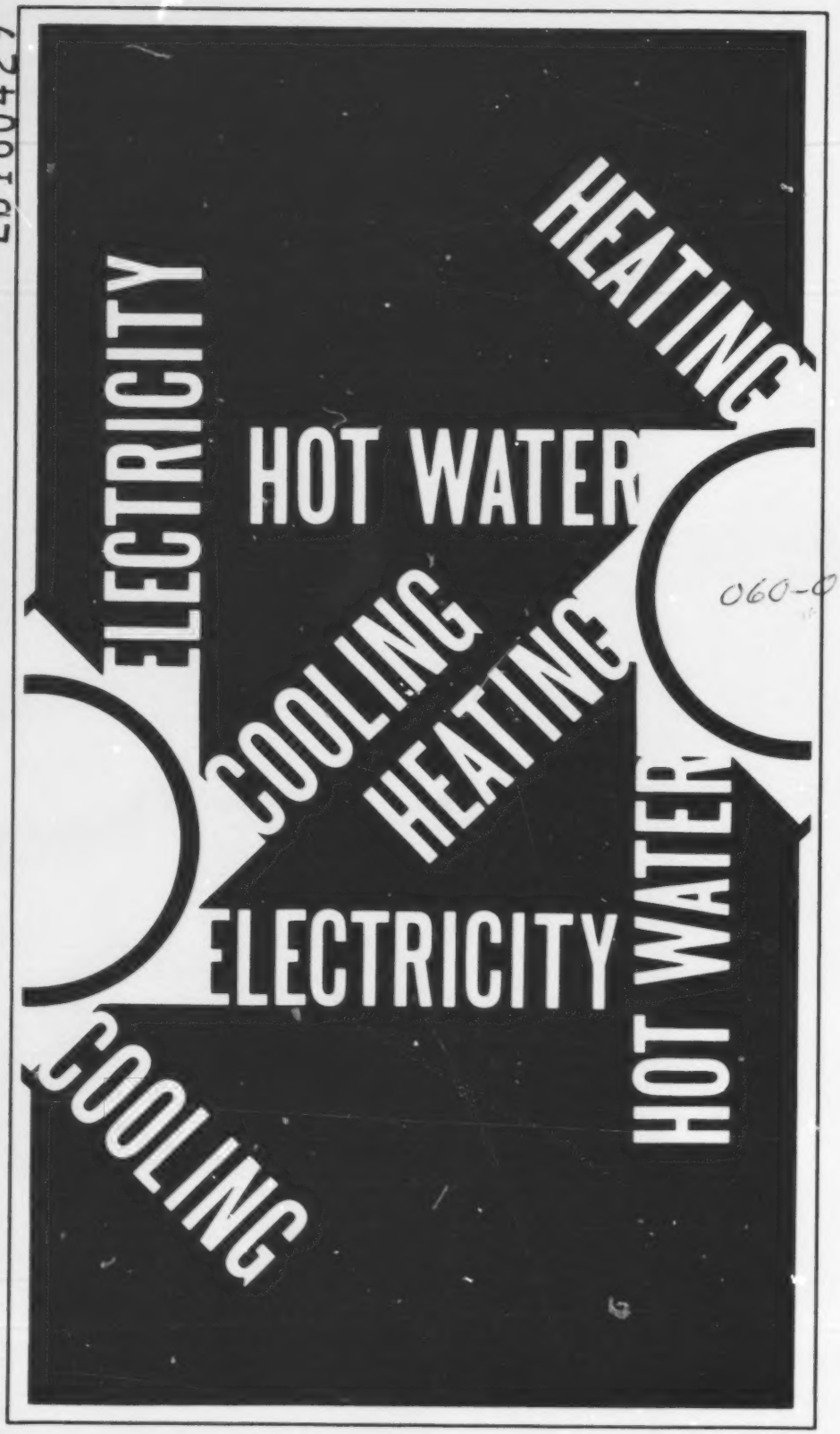

SOLAR PROGRAM ASSESSMENT:

Environmental Factors

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Solar Total Energy Systems

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Environmental & Resource Assessments Branch

Division of Solar Energy

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SECTION I

INTRODUCTION AND ENVIRONMENTAL SUMMARY

A. Organization and Intention of Report

The purpose of this report is to present and prioritize the major environmental, safety, and social/institutional issues associated with the further development of Solar Total Energy Systems (STES). Solar total energy systems represent a specific application of the Federally-funded solar technologies. To provide a background for this analysis, the basic concepts of STES are reviewed, as are their resource requirements. The potential effects of these systems on the full range of environmental concerns (e.g., air and water quality, biosystems, safety, social/institutional structures, etc.) are then discussed in terms of both their relative significance and possible solutions. Although the development of STES will contribute to environmental problems common to any construction project or energy producing technology (i.e., air pollutants resulting from cooling tower "drift"), only those impacts unique to the solar portion of the technology will be discussed in depth. Finally, an environmental work plan is presented, listing research and development proposals and a NEPA work plan which might help clarify and/or alleviate specific environmental problems.

B. Salient Environmental and Safety Issues

Since STES are still largely in the developmental phase, the potential environmental issues presented here and in Section IV of this report are based essentially on technical subsystems studies, extrapolation, and, in some cases, conjecture. The completion of the 5 MW (thermal) Solar Thermal Test Facility and

a number of total energy system demonstration projects in the near future should, however, provide the basis for a more detailed and precise assessment of the environmental impacts of STES.

1. Misdirected Solar Radiation

Misdirected solar radiation from the heliostat field of small scale central receiver STE plants is perhaps the greatest potential safety impact associated with STES technology. Resulting from the emergency or accidental defocusing of the heliostat field from the central receiver unit, concentrated and focused solar radiation can be an invisible but serious, potent danger. This misdirected radiation can cause fires, burns, and serious glare problems with possible eye damage. To protect against possible eye damage and glare problems, plant personnel may be required to wear protective goggles. This problem could be complicated by the proximity of the electric plant to local populations. Provisions for an "at rest" or "face down" position for the heliostats may alleviate some potential dangers resulting from misdirected solar radiation. Finally, both terrestrial and overhead "exclusion areas" could prevent people from being subjected to the hazards of this phenomenon.

2. Proximity of STES to Local Populations

The potential impacts associated with STES take on added significance because of the proximity of the energy producing and storage subsystems to local populations (whether residents or industrial workers). Unlike solar thermal electric central station powerplants, which usually would be located in sparsely inhabited rural areas because of their relatively

large land requirements [1-2 square miles (3-5 km^2) per MWe for the central receiver configuration], STES installations would be sited in relatively highly populated residential communities or industrial areas whenever sufficient land is available. Thus their potential for impacting area inhabitants is much greater, especially in the event of system failures. The proper delineation of exclusion areas and adequate fencing would significantly reduce the likelihood of serious safety problems such as those arising from glare or fluid leakage. Certain protective devices such as goggles could also help to alleviate potential hazards for industrial personnel who work both within or near the energy producing plant. Finally, adequate education of workers and/or local inhabitants as to the potential safety hazards of STES would prove helpful in avoiding injuries.

The above are believed to be the primary potential problems associated with the further development of solar total energy systems. These problems may be offset by a number of beneficial aspects related to STES development. As an alternative energy technology, STES are designed to displace to a certain extent fossil fuel combustion and/or nuclear power generation. Thus STES development can be expected to result in less air, water, and thermal pollution than corresponding conventional systems. In addition, solid waste generation (e.g., ash, scrubber sludges, radioactive wastes) would be significantly less and thus disposal problems would be reduced. The latter would most likely compensate for the relative land intensiveness of STES. Thus the benefits of STES development may balance or outweigh the potential environmental and social costs when all factors are considered.

3. Working Fluid Impacts

Various working, heat transfer, and storage fluids such as hydrocarbon oils and salt solutions are options for use in

STES. The accidental or emergency release of these substances into the local environment could result in potentially serious pollution and safety hazards. From the safety standpoint, fire represents perhaps the greatest hazard. Some of the substances contained in these fluids are highly flammable, especially when exposed to the atmosphere. The release of certain of these fluids could contaminate local water supplies and also damage the ecosystem. Proper system control and maintenance should control fluid leakages. Selection of the least flammable and toxic working fluids should alleviate both potential fire and pollution problems. Finally, adequate chemical/fluid management can control possible impacts of both accidental and intentional fluid release. Such problems are not anticipated if solar total energy systems operate using water, steam, or, perhaps in the long run, various inert gases.

4. Impacts on Utilities

The deployment of STES could significantly impact local utilities and utility/consumer relations. An STES employing a fossil fuel-fired backup system would imply complete independence from the utility network. In the case of industrial STES installations, the utility would be most likely lose cheaper base load demand rather than the more expensive peaking demand. Thus revenues would be reduced, but expensive peaking capacity would still have to be maintained.

Solar total energy systems which rely on utility-supplied auxiliary power may incur pricing schemes which penalize intermittent consumers, because utility companies claim that they must still retain full generating capacity in order to meet demand during periods of extended severe weather when most solar/storage systems will not operate. The construction and maintenance of little-used generating capacity is an expensive proposition which would significantly strain the profitability of most utility companies.

Finally, certain legal problems may arise concerning a utility's legal monopoly on the generation of electricity. Installations which employ STES and thus produce their own electricity would have to seek and obtain permission for this purpose from the proper Federal, State, and local regulatory authorities.

Thus, careful attention should be given to the development of alternative rate structures which would not penalize STES consumers and at the same time enable utilities to maintain sufficient revenues and profits. Contractual arrangements may be worked out whereby an STES installation would provide excess electrical power to the utility. Hopefully, this would enable the latter to reduce its generating capacity to a limited extent. Legal constraints may exist regarding off-site sale of electricity; therefore, the development of STES will require working within or modifying such constraints.

SECTION II

SOLAR TOTAL ENERGY SYSTEMS

TECHNOLOGY

A. General Concepts

The general concept behind solar total energy systems is one of "cascading" energy use. This essentially involves the utilization of waste heat from one building energy function to fuel another building energy function requiring lower temperature energy. This sequential usage, or cascading, of thermal energy typically results in greater overall system efficiency than conventional separate-function systems, primarily because unused or wasted energy is kept to a minimum. For example, average electric power generation cycles operate at 25 to 35 percent efficiency, whereas a solar total energy system is capable of overall energy utilization (electrical plus thermal) in the 60 to 70 percent range.[1/] Solar total energy systems are an application of solar energy technologies. As an application, total energy systems may employ various solar technologies to achieve the desired functions of a given system.

The solar total energy concept may employ a distributed collector configuration or a central receiver system to collect the solar energy which is then used to power an electrical generator. The waste heat from this process is then stored and/or used to meet building heating, cooling, and hot water needs which require relatively lower temperatures than the initial electrical power generating function.

This concept can theoretically be applied to a single building, an industrial installation, an array of detached buildings (e.g., single family residences), or a mixed-load community consisting of residences and buildings of various sizes and heating/cooling loads. The system, however, is subject to

minimum and maximum size constraints owing to the extended collector land area and piping requirements for a large system, and to the high costs of electricity generation and storage for a single small building.

The following analysis is based on a system consisting of 1,000 identical detached single family residences, and essentially follows the Sandia Laboratories design.[1/] Figure II-1 illustrates schematically the Sandia solar total energy concept.

B. Subsystems

The subsystems of solar total energy systems can be divided into two basic functions: electrical power generation and space conditioning. The electric power generation function can be performed via the application of a number of solar technologies. These basically include solar thermal electric (STE) systems such as the central receiver and distributed collector designs. Other solar electric generating technologies are applicable to solar total energy systems. These include photovoltaic cells which generate electricity via photoelectron mechanisms. The waste heat from these reactions can then be used to heat a working fluid for space conditioning applications. The STE technologies will be briefly described below since they are the systems being primarily investigated by ERDA for total energy system applications. Finally, there will follow a description of the remaining subsystems necessary for space conditioning and completion of the total energy cycle.

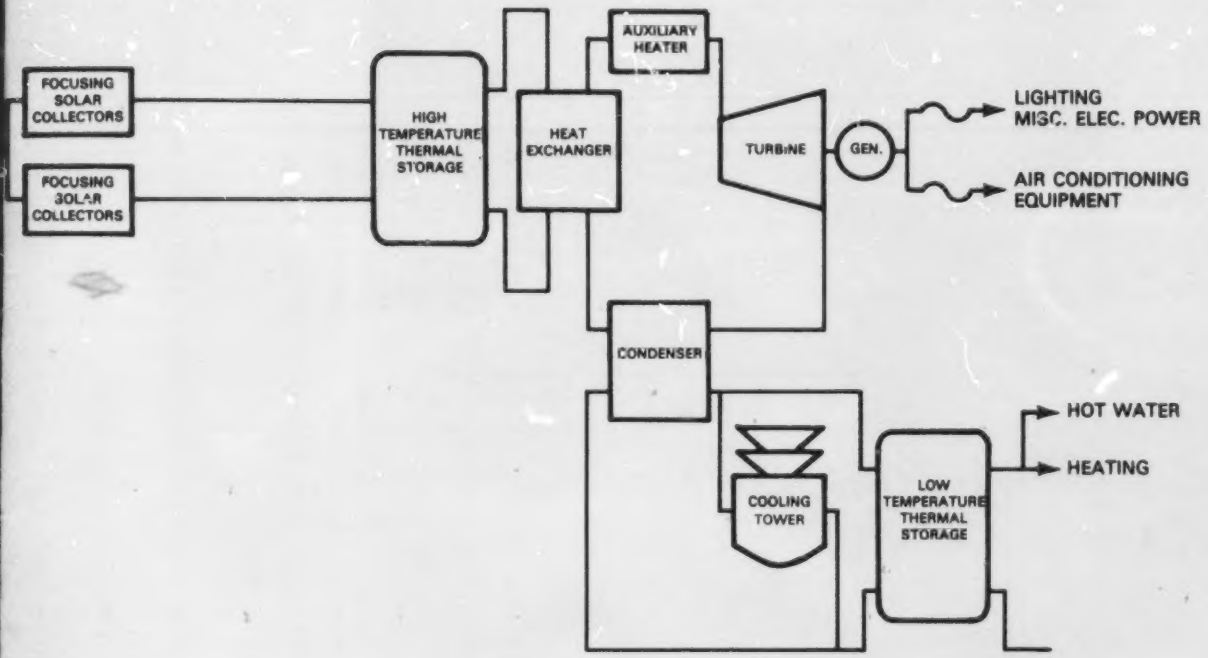
1. Solar Thermal Electric Power Generation

a. Basic Concepts

The basic concept underlying solar thermal electric power generation is the utilization of solar radiation to heat a work-

FIGURE II-1

CASCADED SOLAR TOTAL ENERGY SYSTEM



Source: Duane E. Randall, Conceptual Design Study for the Application of a STES.[2/]

ing fluid to a high enough temperature so that it can be used either directly or indirectly to power a turbine which will in turn drive an electrical power generator, thus producing electricity.

To attain the high temperatures required for this application, concentrated, direct solar radiation is usually necessary (diffuse radiation cannot be focused), thus signifying the need for some sort of focusing collector configuration. Two methods presently exist for attaining these requisite temperatures in working fluid quantities large enough for electric power generation: the distributed collector system and the central receiver system.

b. Distributed Collectors

Distributed collectors refers to a system which employs multiple collection centers for solar radiation as opposed to the single collection point used in the central receiver system. The basic configuration of the distributed collector system is a series of modular cylindrical (parabolic) or segmented mirror focusing collectors with an interconnected abosrber pipe network to carry the solar-heated working fluid to the heat exchanger unit. A series of circular parabolic dish concentrators with interconnected piping is an alternative distributed collector configuration. At the collector piping termination point the working fluid is used to generate steam or some other superheated turbine fluid in order to power the turbogenerator. Since distributed collectors focus direct solar radiation on the absorber, they must incorporate at least a one-dimensional movement mechanism for purposes of tracking the sun across the sky.

Distributed collector systems are generally designed to operate with working fluid temperatures in the vicinity of 550°F - 700°F (285°C - 370°C). [However, the development of secondary concentrators could conceivably increase these operating temperatures to ~930°F (~500°C).] In total energy systems, the design is aimed at maximizing the efficiency of turbine operation. If in doing this the available rejected heat is insufficient to meet heating loads part of the time, then a portion of the working fluid is by-passed to be used in heating or a separate low temperature collector system is utilized.

The working fluids currently under consideration for use in these systems include high molecular weight oils such as Monsanto's Therminol 66, HITEC (a eutectic of potassium nitrate, sodium nitrite, and sodium nitrate), high pressure water, and high temperature steam.

Distributed collector systems can incorporate a thermal storage subsystem. This subsystem usually employs sensible heat energy storage, generally making use of oil or water as the medium. The placement and function of the storage subsystems will be discussed below.

The turbogenerator and heat rejection subsystems employ technology which is currently in wide use in conventional fossil fuel-fired electric generating plants.

Because of their limited working fluid temperatures, pumping losses due to extended absorber piping, and consequent lower conversion efficiencies, distributed collector systems are not ideally suited to large scale power generation. Thus it has been widely concluded that the central receiver system offers the most economic application of solar thermal energy to the production of electricity.

c. Central Receiver

The central receiver system focuses all of the incoming direct solar radiation on a single point rather than along the length of an absorber pipe. Consequently, significantly higher temperatures are attainable with this system than with distributed collectors. These higher temperatures [upwards of 1004°F (540°C)] also result in greater overall conversion efficiencies, typically around 24 percent, for the central receiver system. 3/

The basic system configuration involves the use of arrays of tracking reflecting mirrors called heliostats, which focus solar energy on a single large receiver mounted atop a tower. The working fluid contained in the receiver is heated by the focused solar energy and then piped to the turbogenerator unit (usually located where it is used either directly or indirectly to power a conventional turbine and generate electricity).

The central receiver system consists of five main subsystems:

1) a collector concentrator subsystem to collect solar energy;
2) a receiver heat transfer subsystem to convert solar energy to thermal energy;
3) an electrical power generation subsystem to convert thermal energy to electrical energy;
4) a thermal storage subsystem to cover periods when direct solar radiation is not available, and, optionally,
5) an on-site conventional backup or auxiliary system employing fossil fuel-fired boilers to insure system reliability.

The juxtaposition of these subsystems will vary when central receiver technology is applied to solar total energy systems.

(1) Collector/Concentrator Subsystem

The collector/concentrator subsystem has as its basic function the interception, concentration, and redirection of direct solar radiation to the receiver/heat transfer subsystem. As noted above, this subsystem consists of a field of arrayed heliostats and a tracking control system used to maintain continuous focus on the central receiver. Unlike distributed collectors, the heliostats of the currently most attractive central receiver system must track the sun in at least two dimensions.

(2) Receiver/Heat Transfer Subsystem

The receiver/heat transfer subsystem collects the redirected solar radiation from the heliostats and transfers the solar energy to the working fluid. The fluid is then transported to the electrical power generation subsystem where the thermal energy is used to power a turbine.

The subsystem consists of the receiver support tower, the receiver and boiler units, and the working fluid, which may or may not be the same as the turbine working fluid.

Support towers will vary in height and may be constructed of either steel or reinforced concrete. In addition to supporting the receiver unit, the tower will also contain transfer piping and a maintenance access.

The receiver units presently under development include two basic designs: the planar or direct open receiver and the cavity type receiver. In the planar configuration, the absorbing surface is placed in the open at the focus of the heliostat field. In this position it radiates and convects heat openly to the surrounding air.

To counter the heat loss of an open planar receiver, the cavity concept employs an enclosed receiver unit with an aperture(s) placed at the focal point(s). The focused solar radiation passes through the aperture and strikes the absorbing surface within. Since the outside cavity walls are heavily insulated, heat loss is reduced to that lost through the aperture.

Boiler tubes containing the working fluid are welded to the receiver membrane in a manner similar to standard fossil fuel boilers. Redirected solar radiation from the heliostat field strikes the receiver membrane and tubing, thus heating the working fluid flowing within the tubes.

The choice of working fluids depends upon the type of electrical power generation subsystem in use, the temperatures required to power the turbine, cost, and environmental concerns. Presently under consideration as central receiver working fluids are water/steam (which can be used directly in a Rankine cycle electrical power generation subsystem as the turbine working fluid) and various salt solutions such as HITEC. The hydrocarbon oils mentioned in conjunction with the distributed collector systems generally cannot operate at temperatures greater than 650°F (340°C).

(3) Electrical Power Generation Subsystem

The electric power generation subsystem interconnects the solar thermal conversion and conventional electric power generation technologies. The main function of this subsystem is to transform the thermal energy from the receiver/heat transfer subsystem (the solar heated working fluid) into electrical power. At present, the Rankine cycle is most applicable to solar total energy system use.

The Rankine system is highly developed and is used to generate much of the electricity produced today. Most central

receiver plant designs presently envision the use of a Rankine cycle electrical power generation subsystem with superheated steam as the turbine working fluid. Boiler feedwater is passed through boiler and superheater tubes in the receiver/boiler unit where it is heated by incoming solar radiation to saturated and superheated steam. This superheated steam is then piped down to the electrical power generation subsystem at the tower base where it is used directly to power the turbogenerator unit and produce electricity. Superheated steam in excess of the amount needed to power the turbine is used to "charge" the low temperature thermal storage system which, in turn, supplies space heating and cooling (see below). The turbogenerator unit will employ conventional wet or dry cooling towers for excess waste heat rejection to the atmosphere, if necessary. The turbine condensate (recondensed spent steam) is returned to the boiler feedwater flow line for reheating.

The use of a boiler working fluid which is different from the heat transfer fluid will require a secondary loop using heat transferred via heat exchanger unit. The rest of the electrical power generation subsystem operates in the same manner as above.

(4) Thermal Storage Subsystem

Solar total energy systems will typically employ two thermal storage units: a high temperature system and a low temperature system (see below). The general function of the thermal storage subsystem is to store thermal energy generated by the collector/concentrator and receiver/heat transfer subsystems in excess of that required for normal plant operation, and to supply this stored energy as a buffer at times when direct solar radiation is not available (i.e., because of cloud cover or darkness). In the high temperature storage system, this involves using the stored thermal energy to heat the turbine working fluid temperatures to the level necessary to power the turbine when sufficient temper-

atures for this purpose cannot be generated directly by the receiver and boiler using the focused solar radiation from the heliostat field. As noted above, the low temperature storage system stores waste heat from the turbogenerator and distributes this heat for space conditioning and domestic hot water applications.

At present, thermal storage technology employs the sensible heat transfer and/or latent heat of fusion properties of various storage "media." The latter method involves a phase change and makes use of the relatively narrow freeze-thaw temperature ranges of selected materials such as eutectic salts [for example, molten sodium hydroxide (NaOH) and potassium hydroxide (KOH)]. Sensible heat storage does not involve a phase change but makes use of the high specific heat properties of such materials as rock and hydrocarbon oils.

These storage media are held in storage tanks. In the charge mode, solar heated working fluid (i.e., superheated steam) generated by the receiver subsystem and in excess of the amount needed to power the turbine is diverted to the high temperature storage subsystem and enters the storage tank. The working fluid then transfers heat via heat exchangers to the oil or rock and/or causes the eutectic salt solutions to melt. When storage power is required, the process it reversed with the oil or rock transferring heat back to the boiler feedwater and the salts freezing, thus releasing heat to the feedwater to produce the requisite turbine operating temperatures (i.e., superheated steam).

The high temperature storage subsystem is placed conceptually between the collector and electric power generator subsystems. It typically makes use of sensible heat thermal energy storage and is designed to store fluid at the required turbine inlet temperature. In the Sandia distributed collector concept,

Therminol 66, a hydrocarbon oil and the collector working fluid, is also used as the high temperature storage medium and is stored at 602°F (316°C), which is the design collector fluid outlet/ turbine inlet temperature. The system is sized in relation to the collector area, and is capable of, at most, overnight storage at the design temperature. Fluid sensible heat storage typically involves the use of a properly sized and insulated fluid storage tank.

The low temperature storage subsystem is designed to store the waste heat from the electric power generation subsystem for use in building heating, cooling, and hot water applications. Since the temperatures are lower, the Sandia design employs water as the low temperature sensible heat storage media. Again, the use of an insulated fluid storage tank is required.

2. Total Energy System Applications Using Solar Thermal Electric Power

   a. Electrical Power Generation Subsystem

The Rankine cycle turbine system is used for electrical generation, employing the heat generated by the collector subsystem and/or available from high temperature storage. The turbine and generator are properly sized to meet electricity demand, and are designed to operate at the maximum attainable efficiencies. The waste heat from the turbine is used to provide all or some of the heat for heating, cooling, and hot water purposes.

The Sandia distributed collector system employs superheated toluene as the turbine working fluid. Inlet temperatures from the collector/storage fluid of 602°F (316°C) are required, and the condenser temperature is set at 200°F (93°C) to allow for cooling water temperatures of 190°F (88°C), suitable for absorption air conditioning as well as heating and hot water purposes.[1/]

Therminol 66 is passed through a heat exchanger in the boiler section of the electrical power generation subsystem, where its heat is transferred to the toluene turbine working fluid. The lower temperature [440°F (226°C)] Therminol 66 is then pumped back into the collector subsystem to be reheated.

The cooling water, which is passed through the electrical power generation subsystem condenser to condense the superheated toluene once it has left the turbine unit, attains a temperature of 190°F (88°C) and is then transmitted to the low temperature storage system for distribution to meet heating, cooling, and hot water requirements. The overall estimated efficiency of the Sandia turbine/generator system is 17.9 percent.[1/]

b Heat Rejection Subsystem

Unlike the solar thermal conversion power plant designs, where waste heat from the turbine/generator is simply rejected to the atmosphere, solar total energy systems make use of most of this waste heat. In certain cases, however, excess waste heat must be rejected.

For this purpose, a cooling tower is associated with each storage subsystem. The towers serve to dissipate excess thermal energy when the storage systems are full.

In the Sandia design, the high temperature storage cooling tower is designed to return fluid to storage at 440°F (226°C), whereas the low temperature tower returns fluid at 125°F (52°C). A set of switches senses when the storage systems are at capacity and re-route the fluid directly to the appropriate cooling tower. When the stored thermal energy is reduced, the return fluid is routed directly to the appropriate storage unit, and the associated cooling tower is shut down. Thus, solar total energy system cooling towers may only operate intermittently.

3. Space Conditioning

The thermal distribution subsystem consists of a network of insulated piping and pumps which distribute the heated water from the low temperature storage subsystem to the individual buildings where it is used for heating, cooling, and hot water applications. This piping system then carries the lower temperature [86°F (30°C) drop between exit and return] spent water back to the low temperature storage system.

The piping is sized according to flow and pressure requirements and varies as a result of merging fluid flows. Pumps, valves, and controls are included in the network, as well as provisions for thermal expansion.

Each building employs the hot water from the thermal distribution subsystem for heating, cooling, and hot water purposes, much in the same manner as if the water were derived from individual solar systems. The exception is that a storage system for each building is not required.

Heating is derived essentially by passing air through a hot water coil, while domestic hot water results from a working fluid to potable water heat exchanger in a conventional hot water storage tank.

Cooling is achieved through the use of individual absorption air conditioning units which are designed to function using the hot water from the thermal distribution subsystem. Building electricity is, of course, derived directly from the electrical power generation subsystem.

4. System Auxiliary Equipment

Two fossil fuel-fired furnaces are included in the Sandia system for backup purposes.

One furnace for the high temperature storage system is located conceptually between the turbine/generator and the high temperature storage unit. If the storage volume is below a minimum value, the return fluid from the turbine is routed through the furnace where it is heated to the requisite storage temperature. The furnace will also operate if the temperature in the storage tank is below the minimum value.

The other furnace is located between the thermal distribution subsystem and the low temperature storage unit. It operates in the same manner as the high temperature system. The high temperature and low temperature auxiliary furnaces back up the electrical generation (high temperature storage) and the space conditioning (low temperature storage) subsystems respectively.

Since these furnaces represent auxiliary equipment, they are, of course, designed to operate intermittently.

SECTION III

RESOURCE REQUIREMENTS AND DISPLACEMENT OF ALTERNATIVE ENERGY SOURCES

A. Introduction

The purpose of this section is to provide a basic idea of STES resource requirements and energy displacement. STES sizing and component usage will vary greatly depending upon specific applications. The employment of different technologies, especially in the electricity production function, will cause wide variations in resource requirements as well as in the ability of the system to displace alternative sources of energy.

B. Resource Requirements

The electric generating plant and storage portions of an STES will require relatively large amounts of common materials such as concrete, steel, glass, and aluminum. These requirements for both central receiver and distributed collector systems are presented on a tons/MWe capacity basis in Table III-1. The resources required for the thermal distribution subsystem will consist mostly of metal piping, the amounts of which will vary widely in relation to STES design, layout, size, and the number of individual units to be heated or cooled. Most of those materials are readily available with the possible exception of aluminum, the production of which may be constrained, by reliance on imported bauxite ore. Chrome supplies also stem largely from imports. Materials availability, however, is not expected to be a limiting factor in STES development.

C. Displacement of Alternative Energy Sources

By using solar energy to generate electricity and provide building heating and cooling, solar total energy systems can

TABLE III-1
CRITICAL MATERIALS REQUIREMENTS FOR SOLAR TOTAL ENERGY SYSTEMS (ELECTRICITY GENERATION AND THERMAL STORAGE)

	CENTRAL RECEIVER		DISTRIBUTED COLLECTOR	
Critical Materials	[tons/MWe (metric tons/MWe)]		[tons/MWe (metric tons/MWe)]	
Steel	500-700	(450-630)	700-1000	(630-910)
Concrete	1500-2500	(1360-2270)	500-1000	(450-910)
Glass	50-100	(45-90)	4-6	(3.6-5.4)
Aluminum	20-50	(18-45)	24-30	(22-27)
Copper	5-10	(4.5-9)	5-10	(4.5-9)
Plastic	5-20	(4.5-18)	40-60	(36-54)
Insulation	20-40	(18-36)	25-30	(23-27)
Chrome/Titanium	1-2	(0.9-1.8)	4-6	(3.6-5.4)
Silver	0.01-0.05	(0.01-0.05)	0.005-0.01	(0.005-0.01)
Miscellaneous	5-10	(4.5-9)	5-10	(4.5-9)

Source: MITRE Corp., Analysis & Planning Support for ERDA DSE.[4/]

significantly reduce the consumption of the fossil fuels presently used in these applications. Sandia Laboratories has estimated on a comparative basis the fuel and other operating costs associated with running a 1,000-identical dwelling community. A non-solar total energy system powered solely by fossil fuel-fired boilers would result in 56 percent of the operating costs over the life of the system going toward fossil fuel purchases. Fossil fuels consumed in this instance would still be well below the amounts required if electricity and heating and cooling were provided separately and, in the case of the latter, on an individual basis (that is, if a total energy configuration were not employed). The imposition of a solar thermal electric system to power the turbogenerater, fossil fuel being used only for auxiliary purposes, would further reduce total fossil fuel consumption. It is estimated that solar energy on the average could provide 64 percent of the STES energy requirements, the remaining 36 percent being provided by fossil fuels. Over the life of the system, then, fossil fuel costs could be cut from 56 percent of the overall operating budget in a non-solar total energy system to 19 percent in a solar total energy system.[1/]

SECTION IV

ENVIRONMENTAL AND SAFETY IMPACTS

A. Introduction

Solar total energy systems incorporate a number of solar technologies, and thus the environmental impacts of STES will be of a diverse nature. Essentially, the impacts encountered will stem from the two basic STES functions of solar thermal electricity generation and space heating and cooling. Space heating and cooling is normally a decentralized technology; however, the onsite generation of electricity will mean that solar thermal electric (STE) installations will be in close proximity to area residents and workers. Because of the ability of both of these solar technologies (STE and heating and cooling) incorporated in solar total energy systems to impact significant numbers of people, special attention must be given to both the environmental and safety effects of STES deployments. This section will examine these impacts, concentrating on the solar portion of the technologies. Conventional impacts, such as those stemming from auxiliary fossil fuel-fired boiler operations, will be only briefly addressed.

B. Air Quality

Air quality impacts of STES are expected to be minimal, at least insofar as the solar portion of the technology is concerned. Air quality effects which do result will primarily stem from the conventional and auxiliary equipment associated primarily with solar thermal electricity generation (i.e., conventional fossil fuel-fired auxiliary boilers and cooling towers).

1. Auxiliary Unit Emissions

On-site fossil fuel-fired backup boilers, if used, will

produce the usual combustion-related emissions such as particulates, SO_x, NO_x, CO, and hydrocarbons. The impacts of these emissions will vary with the size and extent of use of the backup units themselves, the type of fuel burned (oil or natural gas will probably be the most common auxiliary fuels because of the relatively high costs associated with coal burning on such a small intermittent scale), and the meteorological conditions at the plant site. These impacts, however, are not peculiar to STES, but are common to fossil fuel-fired boiler operations although emissions from STES will be less owing to the relatively infrequent and intermittent operation of the auxiliary boiler.

In accordance with the Clean Air Act Amendments of 1970, the Environmental Protection Agency has established primary and secondary ambient air quality standards for six major pollutants including particulates and sulfur oxides. The primary standards provide for the protection of public health and the secondary standards for prevention of the many other undesirable effects of air pollution pertaining to public welfare. State and local agencies are responsible for limiting emissions of particulates and sulfur oxides so that the appropriate Federal standards are not exceeded. STES would be subject to these emission regulations and thus air quality impacts resulting from auxiliary fossil fuel-fired boiler operation should be kept within acceptable limits.

2. Cooling Tower Impacts

STES are expected in some cases to employ wet cooling towers for waste heat rejection. These towers through water spraying inject dissolved and suspended solids into the atmosphere as well as create localized fog conditions (cooling tower plume). Impacts on local air quality will vary with plant location and ambient conditions. The use of dry cooling towers (a closed system) would not im-

pact local air quality. Dry towers, however, are not as efficient and are more costly than wet towers in areas with adequate water supply. Cooling towers are not peculiar to STES, but rather are common to all newer electrical power generating systems (i.e., those which do not employ once through cooling and/or are not located near sizable bodies of water).

3. Fugitive Dust

Solar total energy system construction will result in the usual fugitive dust emissions associated with large-scale construction projects. Currently available dust suppression techniques should prove adequate to control construction-related fugitive dust.

Naturally induced fugitive dust (e.g., from wind) could interfere with normal and efficient STES operation. This will most likely result from dust buildups on the heliostat or collector reflecting surfaces which could cause optical interference. To counter this, the heliostat field could be paved or chemically treated.

C. Water Quality

1. Working Fluid Release

a. Solar Thermal Electric Fluids

STES will make use of various heat transfer fluids in association with their receiver/boiler and thermal storage subsystems. Fluids which are currently being considered for STES applications and which are of concern environmentally include hydrocarbon oils and various eutectic or near eutectic salt

combinations. These fluids could be released to the environment and affect local water quality as a result of intentional system flushing operations or accidental leakage. (Periodic system flushing would be required in order to replace degraded fluids or to carry out maintenance.)

The release of these oils or salts could impact the environment in a number of ways. In terms of water quality, their release could contaminate local water supplies. Ingestion of contaminated water would produce serious toxic effects.

Of particular concern are the inorganic nitrates and nitrites (the sodium and potassium salts). Small, repeated injested doses of nitrates deposited in drinking water supplies may lead to weakness, general depression, headache, and mental impairment. In the digestive tract of humans and animals, the nitrates are reduced to nitrites by some of the common intestinal bacteria, particularly the coli bacillus. Because of their anti-bacterial properties nitrites are currently used extensively as food preservatives. They are expecially common in processed and packaged meats.

Ingested nitrites can cause a cell respiratory condition known as cyanosis. Nitrate-nitrogen levels in water above 8-9 ppm can precipitate this illness. The Public Health Service recommends restriction of the daily intake of nitrites in man to 0.4 mg/kg body weight. Nitrites can also induce circulating blood stagnation which results in increased organism oxygen hunger. In addition, ingested nitrites may lead to the formation of a potent class of carcinogens known as nitrosamines (formed via the reaction of nitrites and amines either in water or in the body).

The EPA has established the maximum acceptable concentration of nitrate-nitrogen in raw water used for drinking water supplies at

10 mg/l while the maximum acceptable concentration of nitrite-nitrogen in raw water used for drinking water supplies is 1.0 mg/l. (The latter figure applies to water which would be consumed by infants.) The nitrites would be used as anti-corrosive additives in water systems (i.e., the low temperautre storage and distribution subsystems). Concentrations of these nitrites would vary with the type of metal piping used and the chemical makeup of the water; however, concentrations would generally be on the order of 2,000 ppm. Thus if 10,000 gallons (38,000 liters) of fluid containing nitrite inhibitors leaked into a medium sized [10 billion gallon (38 billion liter)] reservoir, a final nitrite concentration (assuming no nitrites in the reservoir) of 0.002 mg/l would be attained. This would result in a nitrite concentration 500 times below the EPA standard. In general, dilution of a fluid with a 2000 ppm nitrite concentration by a factor of 2000 would be necessary to bring the total concentration of nitrites to the EPA acceptable level of 1.0 mg/l.

The release of heavy oils could also significantly impact water quality. The EPA has stated that oil should be "essentially absent from raw water used for drinking water supplies" since, in any amount, oil will result in taste, odor, and appearance changes and may be a possible human health hazard.

Proper chemical management of system flushing operations should prevent serious impacting of local water quality. Certain of the spent fluids, such as the oils, may be suitable for reclamation processes. It is estimated that from 60-75 percent of degraded oils may be reclaimed using presently available techniques. These reclamation processes, however, may result in secondary environmental impacts. Presently available industrial chemical disposal methods should prove adequate to handle flushed fluids which are not reclaimable. This problem is further mitigated by the fact that flushing operations are expected to occur infrequently.

Fluid leakage and/or spillage would be an accidental occurrence and is not expected as a result of normal STES operation. Proper and periodic system maintenance should be adequate to prevent major fluid leakages. In addition, chemical management procedures (e.g., containment ponds, dikes) should be able to control spillage and/or leakage. Thus, working/storage fluid contamination of area water supplies should not be a major environmental problem if this area of concern is given proper attention during the site development and STES operation.

b. Distribution Subsystem Fluids

Various distribution fluid additives may be used in solar total energy systems to control corrosion of the distribution piping, pH levels, and/or biofouling. The release of these additives into area streams or groundwater could have significant effects. In addition, certain of these additives may potentially contaminate potable water supplies (discussed below). The additives of most concern and their potential impacts are presented here.

(1) Chromates

Both chromate ($Cr\ O_4^{-2}$) and dichromate ($Cr_2\ O_7^{-2}$) salts may be used as corrosion inhibitors in distribution piping. Concentrations of chromates in working fluids would be on the order of 0.9 gm/l. The EPA maximum acceptable concentration of total chromium in raw water used for drinking water supplies is 0.05 mg/l.[5/] Dilution by a factor of 7,000 would bring the total chromium in the water to the EPA standard. If 10,000 gallons (38,000 liters) were emptied into a medium sized [10 billion gallon (38 billion liter)] reservoir, dilution would amount to a factor of a million, thus yielding a level one hundred fold below the standard. The toxic effects of chromates and dichromates will be further discussed in the section on potable water contamination.

(2) Phosphates

Various phosphate solutions could also be used as corrosion inhibitors in distribution system fluids. Phosphorus is a key element in all living organisms. In the protoplasm of plants and animals it is broken down by cellular metabolism or the action of phosphatizing bacteria to dissolved phosphates (e.g., $CaHPO_4$). These dissolved phosphates may be utilized directly in protein synthesis in plants as primary nutrients.[6/] Thus, the release of relatively large amounts of phosphates can generally result in blooms of plankton and algae with consequent reductions in dissolved oxygen content from favorable levels of 10 to 12 mg/l to unfavorable levels of 2 to 3 mg/l. Phosphates can thus affect drinking water because the algal growths tend to impart an undesirable taste and odor to the water. Concentrations in excess of 25 µg/l can result in excessive growths of algae or other aquatic plant life.[5/] Concentrations present in solar total energy systems are expected to be small however, but release of large amounts of distribution fluids could result in possible discernable effects.

(3) Nitrates, Nitrites

The general toxic effects of nitrates and nitrites in man and animals and their potential carcinogenic impacts have been discussed in the section on solar thermal electric fluids. Typically, the nitrate-nitrogen concentrations in lakes and other impounded waters tend to be below 0.1 mg/l.[7/] Nitrates released from STES distribution systems during flushing operations or system failure could increase these levels in local water bodies and groundwater. Increased groundwater concentrations could contaminate wells. Health agencies have generally established a well water nitrate concentration of 10 mg/l.[7/] This concentration could be exceeded if a leak occurs in a large distribution subsystem located in the vicinity of wells and the discharge is allowed to infiltrate to groundwater.

In addition, nitrates, nitrites, and "fixed" (incorporated into chemical compounds) nitrogen in the form of ammonia are common basic nutrients in aquatic ecosystems. The release of these substances into lakes and rivers could stimulate floral growth resulting in the undesirable effects associated with eutrophication. The dissolved oxygen content of the water could thereby be reduced, with consequent harmful effects to fish. The concentrations and thus the impacts of these substances are not expected to be serious, however, due to the volumes needed to produce these effects at a noticeable level.

(4) Sulfites, Sulfates

Certain sulfate solutions such as sulfuric acid and sulfide solutions such as sodium sulfide may be added to distribution fluids as pH controllers, biocides, and corrosion inhibitors. The sulfides can be decomposed to hydrogen sulfide (H_2S) by bacterial action, and the H_2S is further oxidized to sulfates such as ammonium sulfate (NH_3SO_4).[6/] As in the case of phosphates, nitrites, and nitrates, sulfates are used by plants as primary nutrients. Related problems associated with eutrophication can result. In addition, the release of these substances could result in increased salinity and pH levels with possible harmful effects to aquatic life. The EPA maximum allowable concentration of sulfates in freshwater used for drinking water supplies is 250 mg/l, while the maximum concentration of sulfides for freshwater aquatic life is 0.002 mg/l.[5/] The levels of concentration evidenced in distribution subsystems, however, are not expected to pose significant problems.

The Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems (published jointly by the National Bureau of Standards and the Department of Housing and Urban Development) offer a series of guidelines for the proper containment and disposal of released liquid working fluids.[8/] These guidelines are generally in relation to solar heating

systems, but they are also applicable in some cases to STES distribution fluids. These guidelines require that:

1. A list of the chemical components of the heat transfer medium (i.e., the distribution fluid) must be provided in mg/l. This list must include any substances which comprise more than 0.10% of the medium.

2. The organic constituents of these substances must have a five-day biochemical oxygen demand (BOD), using sewage seed, of at least 70% of the theoretical oxygen demand. This test shall be in conformance with the Standard Methods for the Examination of Water and Waste Water, American Public Health Association (1971).

3. The concentration of chemical constituents must be compared with the 96-Hour LC-50 (Lethal Concentration) bioassay value for protection of aquatic life. This comparison is to be made in accordance with the Water Quality Criteria, 1972.

Further research into chemical distribution fluid additives is required in order to assess their potential impacts on water quality. Adoption of the above Minimum Property Standards (MPS) guidelines by local administrative and regulatory authorities should insure that STES distribution system fluids will not seriously impact the environment.

(5) Impacts on Sewage Treatment Facilities

STES distribution fluids may be flushed through the existing sanitary sewage facilities and enter local sewage treatment plants. In this case, the impacts of chemical constituents on sewage treatment operations should be investigated. Distribution

fluids which are biodegradable and sufficiently diluted may be flushed through conventional sewage systems. The following methodology is required in the MPS:

> Using the gallon/day capacity of the local sewage treatment plant, approximate the concentration at the treatment plant. If the dilution of the chemical constituents is 1/10 the LC-50 value or greater at the sewage treatment plant, the heat transfer (distribution) medium must be diluted before emptying into a public sewer.[8/]

The MPS also provide for an adequately sized catch basin to be used in conjunction with hazardous distribution fluids. This basin would serve to hold flushed distribution fluid during system repairs or until it can be properly disposed of (i.e., by being trucked away to a chemical dump). In addition, the catch basin should be adequately sized to allow dilution in accordance with the sewage disposal provision presented above.[8/]

(6) Potable Water Contamination

STES distribution fluids will be used to supply space heating, cooling, and domestic hot water (usually via heat exchangers). Because of this interface between possibly hazardous distribution fluids and potable water supplies, contamination of the latter may result in potentially harmful consequences.

Particularly dangerous distribution fluid components are the nitrates/nitrites and the chromates and dichromates. The toxic effects of the nitrates/nitrites have already been discussed in the section on solar thermal electric fluids.

Undiluted chromate contaminated water could pose a health problem if the water were ingested. Concentrations present would be on the order of 0.9 gm/liter (less than 10^{-2} molar). This is about 0.4 gm/liter of chromium.

The EPA has set the maximum acceptable concentration of total chromium in raw water used for drinking water supplies at 0.05 mg/l, giving the following rationale:

> The necessity of restricting concentrations of total chromium to 0.05 mg/l or less results from its adverse physical effects on humans and the fact that there are insufficient data concerning the effectiveness of the defined treatment process in removing chromium in the chromate form. Chromium, in its various valence states, is toxic to man, produces lung tumors when inhaled, and induces skin sensitizations. It occurs in some foods, ir air, including cigarette smoke, and in some water supplies. No-effect levels for chromate ion on man have not been determined. The prescribed limit of 0.05 mg/l was established to avoid jeopardizing the public health by the presence of chromium in drinking water.[5/]

A serious problem with the use of chromates, or any other working fluid, is the potential for contamination of domestic water supplies. The likelihood of water supply contamination is highest for systems with direct exchange of heat between the distribution fluid and the hot water supply. Even a small leak in the heating coil in the hot water heater can result in contamination of the hot water supply beyond EPA's maximum acceptable standard. To reach the EPA standard of 0.05 mg/l, about 0.008 gallons (0.03 l) of working fluid would have to leak into a nominal 50 gallon (190 l) hot water heater. It must be kept in mind this standard is for chronic exposure. The amount required to produce acute symptoms over a short term ingestion period is likely to be higher.

The substances presented above are expected to be those of most serious concern. Yet many other fluids and additives are being considered for STES use. Additional investigation of potential distribution fluids and additives is necessary to insure the safety of their use in solar total energy systems. Research and development work is underway with the goal of developing effective, nontoxic, and inexpensive distribution fluids for STES use.

In the meantime, a number of steps can be taken to guard against potable water contamination. Several of these are outlined in the Minimum Property Standards.[8/] These include:

- separation of circulation loops between nonpotable distribution fluids and the domestic potable water system;
- identification of nonpotable fluid and potable water systems by color-coded piping or metal tags; and
- nonpotable fluid leak indicators, such as harmless vegetable dyes.

In addition, proper double wall heat exchanger systems can provide a high degree of protection against potable water contamination. These systems are illustrated in Figure IV-1.

D. Land Use/Solid Waste

1. Foregone Use of Land

Land use is an important consideration in STES deployment, primarily becuase of the relatively large land areas required for solar thermal electric generation.

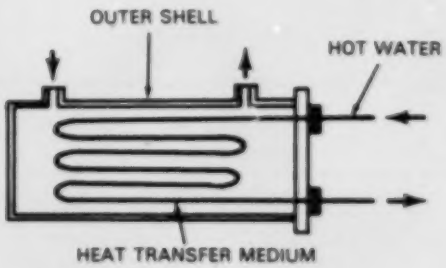
STES land requirements may thus conflict with alternative land uses or area land use plans. This would be especially true in densely populated residential and commercial areas or areas of concentrated industry such as industrial parks. In such areas, land is at a premium and thus high in cost with conflicting claims as to its proper use.

To mitigate these potential conflicts, planning officials and the public should be educated on the relative cost-benefits and tradeoffs between STES and fossil fuel or nuclear powerplants.

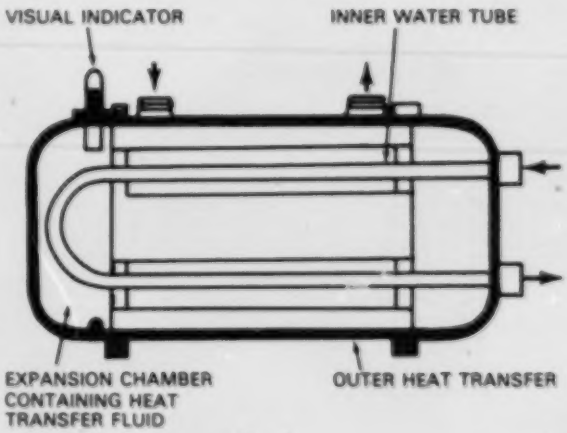
FIGURE IV-1
HEAT EXCHANGERS

HEAT EXCHANGERS A heat exchanger is a device for transferring thermal energy from one fluid to another. In some solar systems, a heat exchanger may be required between the transfer medium circulated through the collector and the storage medium or between storage and the distribution component. Three types of heat exchangers that are most commonly used for these purposes are illustrated below.

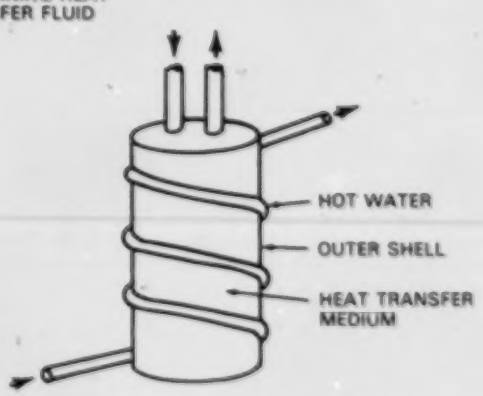
SHELL AND TUBE This type of heat exchanger is used to transfer heat from a transfer medium containing antifreeze to water used for storage. Sheel and tube heat exchangers consist of an outer casing or shell surrounding a bundle of tubes. The water to be heated is normally circulated in the tubes and the hot liquid is circulated in the shell. Tubes are usually metal such as steel, copper or stainless steel and the shell is often steel for solar applications. A single shell and tube heat exchanger cannot be used for heat transfer from the toxic liquid to potable water because double separation is not provided and the toxic liquid may enter the potable water supply.



SHELL AND DOUBLE TUBE This type of heat exchanger is similar to the previous one except that a secondary tube is located in the shell. The heated liquid circulates between the shell and the second tube. An intermediary non-toxic heat transfer liquid is located between the two tube circuits. As the heated liquid circulates through the tube, the intermediary is heated which in turn heats the potable water supply. The heat exchanger can be equipped with a sight glass to detect leaks—toxic liquid often contains a dye—or to increase the liquid level in the intermediary chamber.



DOUBLE WALL Another method of providing a double separation between the transfer medium and the potable water supply consists of tubing or a plate coil wrapped around and bonded to a tank. The potable water is heated as it circulates through the coil. When this method is used the tubing or coil must be adequately insulated to reduce heat losses.



Source: NBS, Minimum Property Standards for Solar Systems.[8/]

The relative land-intensiveness of STES is balanced by a number of factors. Among these are 1) the fact that STES do not generate radioactive wastes which require long term isolated storage either above or below ground, 2) STES do not typically generate the solid wastes associated with fossil fuel-fired powerplants (i.e., ash) which require on or off-site disposal, and 3) STES are relatively non-polluting in terms of air, water, and thermal pollution. Thus, a case could be made for the benefits of STES outweighing, or at least balancing, the costs in terms of relative land intensiveness and consequent displacement of other land uses.

2. Backup Unit Residuals

STES may employ on-site fossil fuel-fired backup boiler units for use during periods when direct solar radiation is not available. These units will generate the solid wastes)ash) typically associated with fossil fuel-fired boilers. Such wastes will require either on or off-site disposal. This problem is not peculiar to STES, but is common to any fossil fuel-fired boiler. In addition, this problem is not expected to be significant since the backup units will be used on a relatively infrequent and intermittent basis and will probably use oil or natural gas as fuels. The combustion of these fuels does not generally produce solid wastes in the same quantities as coal combustion.

E. Ecological Impacts

1. Working, Storage, and Distribution Fluid Release

As noted above in Section C (Water Quality), the various working/storage fluids used in solar thermal electricity generation may be released into the environment as a result of flushing operations or leakage. These fluids, mainly hydrocarbon oils and eutectic salts, may potentially affect the ambient ecosystem.

This is especially true for the oils, which may suffocate certain organisms by impairing the ability of surface cells to breathe. The salts appear to be somewhat less of a danger. Their release can be expected to result in an increased soil salinity which may affect local soil and floral communities. When a water solution containing a relatively large amount of dissolved salts comes in contact with plant cells, a shrinkage of the protoplasmic lining is caused. This process is known as "plasmolysis," and the shrinking action increases with the concentration of salts. Plasmolysis is caused by the osmotic movement of the water which passes from the cell toward the more concentrated soil solution, and ultimately results in cell collapse. The precise salt concentration necessary to induce this phenomenon is a function of the nature of the salt, the plant species, and the type of soil, among other factors. Certain plants, such as sugar beets, cotton, and western wheat grass have a relatively high tolerance to saline soils, while peas, cabbage, and certain types of clover have a low tolerance level.

The EPA has recommended that waters used for irrigation have a total dissolved solids (TDS) concentration not in excess of 2000-5000 mg/l for tolerant crops, and 500-1000 mg/l for sensitive crops. Thus, if 100 pounds (45 kg) of salts (in solution) were released, dilution by a factor of 24,000 would be necessary to attain the EPA recommended TDS levels for sensitive crops. This would be equivalent to spreading the salts dissolved in water over 1 acre (4047 m^2) of land at a depth of 1 inch (2.54 cm). The impacts of increased salinity due to salt solution release should not be significant, however, owing to the localized nature of the emission. Proper containment measures (i.e., retention dikes) could also help alleviate this problem.

The effects of working/storage fluid release on the ecosystem would be insignificant if preceded by the removal of vegetation and the paving or treating of the collector or heliostat field during plant construction. In addition, proper management and system maintenance should prevent fluid leakages or spillage. The proper containment, removal, and disposal of intentionally flushed fluids should prevent their impacting local ecosystems. In this regard, flushed oils could be burned, recycled after treatment, or removed from the plant site and properly disposed of. Salts may be retained in catch basins until properly disposed of off-site in chemical dumps.

The impacts of distribution fluids and additives on water quality and aquatic life have been discussed above. Distribution fluid leakage could also potentially harm local flora and fauna. Proper containment facilities, such as catch basins, should prevent the release of working fluids from significantly impacting local ecosystems.

Salt deposition (consisting mostly of sodium chloride and certain other metal chlorides, depending upon the makeup of the cooling water) resulting from wet cooling tower operation (in association with absorption air conditioning) could also cause harmful effects to nearby foliage, as well as increase local soil salinity. Emission levels are expected to be quite small, however, and thus impacts resulting from salt deposition are not expected to be significant.

2. Collector Field Impacts

The heliostat or collector units may produce significant shading effects which could potentially impact local ecosystems. Numerous floral and faunal species could be attracted to the shaded areas under these units where they may thrive, thus creating system imbalances and/or impediments to collector

operation and maintenance personnel. Control of these shaded area microcommunities through various techniques may prove necessary. Paving or chemical treatment (oil application) for dust control purposes would eliminate floral growth as would the localized application of herbicides. In addition, the absence of floral growth and the presence of maintenance personnel should render the heliostat field undesirable as a faunal habitat.

F. Safety Issues

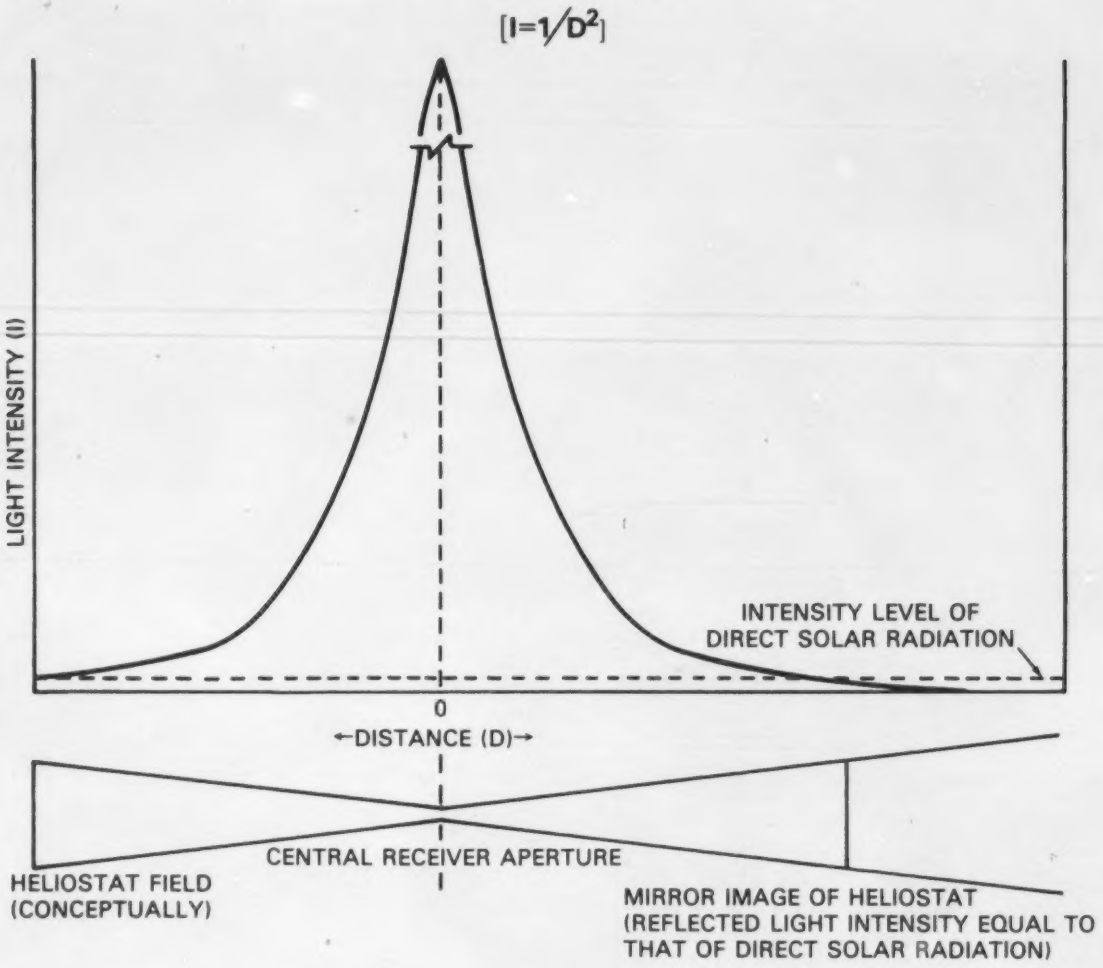
1. Misdirected Solar Radiation

The greatest potential safety hazard associated with STES which employ central receiver solar thermal electric plants is that which stems from misdirected solar radiation caused by a misaligned heliostat field. This invisible concentrated and focused solar radiation can potentially cause fires and burns as well as create serious glare problems.

At the focal point of the heliostat field there is a concentrated beam of focused radiation. Beyond the focal point, this beam becomes increasingly dispersed and eventually becomes more diffused than the original solar radiation. Thus there is a range around the focal point where the beam is significantly concentrated as to present a potentially serious safety hazard. This is conceptually illustrated in Figure IV-2. Typically, the focal point of a properly focused heliostat field coincides with the central receiver. An out of focus heliostat field, however, will cause the focal point to occur a certain distance away from the central receiver.

The most serious potential impacts of a misdirected heliostat field will occur in the range of concentrated radiation around the focal point. The intensity of the beam in this region would be sufficient to cause blinding and severe burns. In addition, any type of combustible material could be easily ignited. In most cases, the distance to the focal point will be relatively limited; thus most burn or fire impacts would be limited to the

FIGURE IV-2
VARIATION IN REFLECTED LIGHT INTENSITY OVER DISTANCE ASSUMING NO INTERCEPTION BY THE RECEIVER


[I=1/D²]
LIGHT INTENSITY (I)
INTENSITY LEVEL OF DIRECT SOLAR RADIATION
0
←DISTANCE (D)→
CENTRAL RECEIVER APERTURE
HELIOSTAT FIELD (CONCEPTUALLY)
MIRROR IMAGE OF HELIOSTAT (REFLECTED LIGHT INTENSITY EQUAL TO THAT OF DIRECT SOLAR RADIATION)

Source: EEA, Inc.

main STES plant site. At a distance twice that of the focal point, the beam will disperse to the point where it represents a sharp glare similar to direct sunlight (see below).

STES operating and maintenance personnel should be instructed concerning the possible effects of misdirected radiation. Some type of protective goggles fashioned from materials such as photochrome or rapid rise glass should also be worn by all personnel in potential danger areas. Heliostat systems should be designed for quick and safe emergency shutdown, and should be kept in a face down "rest" position when not in use. In addition, all potentially combustible materials should be stored in places inaccessible to misdirected radiation. Furthermore, buildings and access roads should be constructed out of the pathways of possible misdirected radiation.

It should be noted that in certain solar total energy system applications, heliostats will likely be individually focused. Thus even one misaligned heliostat could result in burn, fire, or glare hazards. It is therefore essential to educate area residents and workers, as well as plant personnel, about the potential dangers associated with misdirected solar radiation. Exclusion areas and fencing (see below), where appropriate, should also help alleviate potential problems.

While not as hazardous as burns or fire, glare is a potentially serious problem resulting from misaligned or even properly aligned heliostats. This is due to its ability to impact both on and off-site receptors as well as those in overflying aircraft. The intensity of this glare will be a function of the distance of the receptor from the heliostat field or individual heliostat producing the glare. As this distance increases, the intensity of the glare will decrease. Aside from affecting STES personnel, glare can also affect the operators and passengers

of motor vehicles on nearby roads or in overflying aircraft. Accidents could occur as a result of temporarily blinded vehicle operators. To guard against this danger, the STES electrical plant should be designed and sited such that heavily-used public roads or highways will not be subjected to frequent glare. The solar thermal electric plant site itself should have perimeter fencing to insure that trespassers are not harmed by glare or burned. (Fencing would also guard against vandalism.)

In relation to aircraft, it may be necessary to restrict planes from flying over STES sites. Regulations to this effect could be administered by the Federal Aviation Administration. Thus, protective devices for STES personnel, coupled with proper layout and exclusion areas, should mitigate the serious impacts of glare.

The above discussion is not intended to imply that many of the potential hazards of heliostat use cannot be mitigated. Handled carefully, problems of misdirected reflected light can be minimized. However, it is anticipated that, particularly in the technology's infancy, accidents of a serious nature can and will occur. Just in the very limited experience to date in heliostat research, accidents have occurred due to an underestimation of this hazard's potential. A worker at a test facility experienced a severe burn on the hand when he went to move an oil drum in the path of a misdirected heliostat. On another occasion, a tent surrounding an experimental heliostat burned to the ground when the tent flap blew open on a weekend and the heliostat was exposed to direct sunlight and ignited the tent. On a third occasion a truck driver using a construction road near a test site drove through a diffused post-focus beam presenting a bright glare and potential driving hazard. The driver's union contacted the test facility and a protective barrier was eventually constructed.

2. Working Fluids: Safety and Handling

a. Molten Salts

In the design of an STES electric power plant, various heat transfer substances have been postulated as working fluids, secondary heat transfer media, and heat storage media. These include molten eutectic salt mixtures that contain alkali nitrites, nitrates, and hydroxides (primarily $NaNO_2$, $NaNO_3$, NaOH). Heat storage and transfer media of this category typically operate below 570°F (300°C) and are commonly comprised of sodium and potassium salts in ratios that form a desired eutectic mixture.

The compounds of concern in the eutectic salt mixtures are primarily the nitrite and nitrate salts of sodium of potassium. Their potential for hazard is not encountered under normal operation, but under certain adverse conditions they can contribute synergistic effects to combustible materials, increasing their flammability and the intensity of fires. When exposed to temperatures above 716°F (380°C), sodium nitrate ($NaNO_3$) will decompose releasing oxygen and forming sodium nitrite ($NaNO_2$) which will also decompose at high temperatures. At greater temperatures [around 1830°F (1000°C)] or when subjected to extreme shock, closed containers of substances can rupture or explode.[9/]

These molten salt mixtures will not, under normal operation, be exposed to conditions that will cause their decomposition. Their potential for hazard, however, is manifest in their release of oxygen upon decomposition encountered under adverse conditions. In a worst-case example, it may be postulated that these nitrate compounds could become exposed to extremely high temperatures, as during a fire, rupture their containers, and fuel the intensity of an existing fire with oxygen (from decomposition).

In relation to oxidizing properties, sodium nitrate and sodium nitrite behave similarly (the potassium nitrate/nitrite analogs are similar to the sodium compounds and therefore need not be discussed). When accompanied by combustible materials, $NaNO_3$ and $NaNO_2$ pose a severe fire hazard. Generally, nitrate-flammable mixtures require an ignition source before they burn; however, once ignition occurs, violently rapid combustion[9/] is possible, even explosion. Indeed, sodium nitrate is such a powerful oxidizer (or oxygen carrier for reactions) that it is used in straight dynamite. Fire problems are further compounded by the release of nitrogen oxides accompanying the decomposition of the nitrates and nitrites. These oxides are toxic, and self-contained oxygen gear must be worn when fighting a nitrate-nitrite induced fire.

Storage and handling of $NaNO_3$ and $NaNO_2$ must also be done with prudence as they are hygroscopic compounds which absorb moisture either from the air or material they contact, thereby increasing the potential for combustion. Again, proper handling practices are well documented and, under these conditions, $NaNO_3$ and $NaNO_2$ are safe.

b. Oils

Hydrocarbon oils can also pose a potential fire or burn hazard. At temperatures of approximately 356°F (180°C) the oil vapors will combust if exposed to air (this is known as the "Flash Point"). The "Fire Point," at which the liquid oil itself will combust, is typically at temperatures of approximately 381°F (194°C).[10/] These hydrocarbon oils will usually be hot enough to cause severe burns if they come in contact with the skin.

Under normal operating conditions, heated hydrocarbon oils will not be exposed to air and thus combustion should not occur. Proper system maintenance should prove adequate to control possible leaks of heated oil which could result in oil fires. In addition,

proper handling and protective gear should prevent serious burns. The hydrocarbon oils being considered for STES applications are not new, but rather have been in industrial use for quite some time. Thus, fire and burn safety procedures and proper handling techniques are generally well understood and fairly easily employed at STES installations.

c. Liquid Metals

Liquid metals, primarily sodium, may be considered as a long term future option for use in central receiver systems as heat transfer fluids. In many cases, liquid metals present significant environmental and safety problems Because liquid metals are considered a long term option, the implications of their use are not presented here. An in depth discussion of the environmental and safety implications of liquid metals is presented in a report on solar thermal electric systems by Energy and Environmental Analysis, Inc.[11/]

3. Receiver Tower Impacts

A potential safety hazard peculiar to the central receiver solar thermal electric design is the receiver tower. Depending upon the actual plant design finally adopted, there could be one or more towers 350 to 900 feet (107 to 275 m) high. This compares with taller skyscrapers in the range of 25-75 stories. Typical utility stacks, on the other hand, average between 200 and 300 feet (61-92 m). The receiver towers could pose potential safety hazards to aviation in the area. Both commercial and civil aviation would be affected. Receiver towers should thus conform to FAA regulations as to proper lighting and placement. In addition, the prohibition of STES overflights would significantly reduce any danger to aviation resulting from tall receiver towers (as well as glare).

Since the tower is designed to support the boiler system, proper construction methods will be employed to guard against possible damage or collapse due to seismic activity. However, even minor tower damage could result in the rupture of pressurized working fluid transfer lines which connect the boiler unit with the turbogenerator located at the tower base. Seismic problems are especially acute in relation to distributed collector systems. This is because distributed systems have much greater piping distances and thus more connections and fittings with a correspondingly higher probability of piping system failure. Thus the potential for rupture and working fluid leaks may be greater with distributed collectors than with the central receiver system. Careful geologic analyses of prospective STES sites should pinpoint area fault lines and determine the relative probability of significant seismic activity in the near future. Based on these studies and proper siting and construction methods, the risk of serious seismic damage can be significantly reduced.

4. Worker Safety

Because solar total energy systems will comprise fairly sophisticated technologies, professional engineering support will be required of the operator. Thus the potential for accidents due to inexperience or lack of understanding will be lessened. In addition, the centralization of the STES electrical generation and thermal storage plants should preclude potential hazards resulting from the attempts of the inexperienced home handyman to repair or adjust his individual solar heating or cooling system.

G. Esthetics

1. Visual Impacts

The visual effects of solar total energy systems will vary greatly, depending upon their specific uses. The greatest visual

impact will be the solar thermal electric generating plant and thermal storage subsystems. A central receiver STE plant will consist of a tower and a heliostat field. Both will present a unique and unfamiliar appearance. In industrial areas, the STE plant will generally fit in well, appearing as an industrial installation of some sort. In residential areas, however, the STE plant will contrast markedly with surrounding streets and homes or apartments. The tower, turbogenerator, and storage tanks will appear as a somewhat out of place industrial plant.

The individual buildings which are supplied with heating, cooling, and domestic hot water generally will not be esthetically unpleasing. The only noticable elements may be the individual cooling tower units associated with building absorption air conditioning. These cooling towers will be small, however, resembling conventional central air conditioning units. Added piping and pumps may be necessary, but these are not expected to create significant visual impacts. The STES buildings, in general, should remain essentially unchanged from the visual standpoint.

2. Noise

The boilers and turbogenerators of the STE plant will create the usual noise levels associated with steam electric generation. The cooling towers associated with each storage subsystem will also be a major source of noise. In industrial settings, these noise levels will not add greatly to ambient conditions and will typically be indistinguishable from general industrial plant noise. In residential areas, however, the STE and storage systems could add significantly to ambient noise levels. This problem is mitigated, however, by the intermittent and relatively infrequent use of the storage system cooling towers, which would be the main sources of noise in solar total energy systems.

The distribution system and individual heating and cooling systems can be expected to generate limited amounts of noise as a result of pump and blower operation. In addition, absorption unit cooling towers could generate low level noise (typically less than the HUD "acceptable" criteria of 45 dBA). The impacts of distribution and heating/cooling noise are not expected to be significant, however, owing to the relatively low noise levels which would result.

H. Social and Institutional Impacts

1. Impacts on Utilities

The deployment of solar total energy systems could significantly impact local utilities and utility/consumer relations. The precise impacts will depend to a large extent on the size and application of the STES and the type of auxiliary capability it employs (whether on-site fossil fuel-fired boilers or utility supplied electricity). In all cases the utility will not receive the revenue from the sale of the displaced electricity. Thus the most important consideration is whether or not the utility's costs will be decreased sufficiently to compensate for the reduced revenue. Utility costs can be broken down into fixed costs, for plants and equipment, and variable costs, for fuel. A decrease in electricity demand will change the amount of fuel used by the utility but may not change the necessary amount of generating capacity. The off-peak demand for electricity will decrease but the utility may still have to maintain a high generating capacity for the peak period demand. The impact of the deployment of the STES will, thus, be determined by the relationship between the total reduction in electricity demand and the reduction in demand during the utility's peak hours.

An important factor in this analysis now becomes the back-up source of energy that the user plans to utilize when the sun

does not shine and the solar system fails. A back-up system that is independent of the utility, e.g. fossil fuel, will result in no utility electricity use. In this situation users that would use a lot of electricity during the utility's peaks, e.g., commercial and residential buildings, will tend to raise the utility's capacity factor* and even out its load by using STES instead. If the user has a fairly constant energy demand, e.g. an industrial operation, then the utility will lose a base load user. This will lower the capacity factor and cause greater fluctuation in the utilities demand.

If the STES displaces electricity demand then it is likely that electricity will be used as a back-up fuel. In this case the utility will not be able to lower its generating capacity will have to maintain the capacity so that if the STES fails during a utility peak the utility can supply the necessary electricity. This effect will be lessened if the user can utilize the STES's storage system and store off-peak energy. A utility with a summer peak will also have fewer problems of this type since the longer and more frequent sunny days will make a STES failure less likely during a utility peak.

2. Building Code Adaptation

Local building codes may impose barriers to STES deployment, especially in residential applications. Building code impacts may be potentially severe because building codes are imposed and administered on a municipal basis rather than through centralized State or Federal processes. Building code laws generally contain no provision for judicial challenge or review of standards, en-

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* The capacity factor shows the ratio between the actual output of the utility and maximum possible output.

$$C.F. = \frac{\text{Annual Utility Output (kwh)}}{\text{Total Utility Capacity (kw)} \times 8760 \text{ hrs.}}$$

forcement, or administration. Potential legal remedies include anti-trust actions based on undue restriction of energy alternatives, review of regulations to determine whether they unduly restrict an owner's use of property without due process of law, and invocation of interstate commerce provisions for Federal review of State laws which unduly burden interstate commerce.[12/] Potential Federal actions, such as a national building code or a system of State code certification tied to Federal grants, are generally considered unrealistic in terms of monetary and manpower expense, although HUD's revised MPS are expected to serve as a useful model for State or locally initiated revision of codes. A review of current research and experience with solar heated installations indicated that no serious conflicts have arisen or are expected to arise between local building codes and solar system users.[12,13,14/] This, however, may not be the case with solar total energy systems.

In general, though, STES are energy savers and thus politically attractive. Therefore, several States have enacted legislation requiring new buildings to have the capability to accommodate solar heating, cooling, and hot water systems. Such regulations are expected to greatly minimize future building code conflicts.

Solar builders and researchers agree that education and cooperation of officials at the local level is the most crucial requirement in resolving building code conflicts. As one researcher summarized, "The building code dilemma must be resolved at the local level with the aid of people who have been involved in modelling codes in the past as well as solar energy people."[14/] Public education as to the energy saving potential of solar total energy systems should facilitate this process.

3. Zoning Regulations

Zoning regulations are based on the police powers of the government and fall within the grant of powers to towns and cities. In essence, zoning regulations restrict the ways in which owners may develop or use their land in the interest of the

public health, safety, morals, and general welfare. Zoning regulations are largely initiated and administered at the municipal or county level and although there is a trend towards regional and Statewide zoning plans, their administration is often hampered by lack of funds, lack of interest, haphazard reporting, complexity, expense, and fragmentation of administrative procedures.[15/]

Land use controls other than zoning include personal covenants or easements and subdivision requirements imposed on developers specifying services to be provided in compensation for the additional demands on community resources caused by incoming residents. In general, subdivision requirements for large developments such as residential areas, shopping centers, and industrial parks (all potential STES users) tend to be broader and more flexible than those for other land uses.[12,16/]

Zoning requirements which may restrict the use of solar total energy systems include height limitations and provisions for building appearance or esthetic review. These impacts would be particularly severe for solar total energy systems. Cooperative systems involving collectors or storage shared among several property owners such as a community owned STES might also violate restrictions on property use, although this has not occurred to date. Where zoning regulations are incompatible with proposed solar total energy systems, variance procedures are costly, time-consuming, and uncertain, with wide variations among various localities. Furthermore, zoning regulations are not readily subject to judicial review, so each situation must be considered on a case-by-case basis.

As with building codes, changes in zoning regulations are most likely to be successful when approached at the local level, although comprehensive regional and Statewide regulations provide a useful model framework. Modifications of current zoning and land use regulations to promote solar energy utilization have been proposed

on the basis of extending the interpretation of public welfare to include the benefits of decreased dependence on non-renewable and environmentally taxing energy sources. The goal of such modifications would be to remove physical restrictions on height, bulk, location, and appearance of solar components, and also to ensure access to sunlight, which is discussed in greater detail below. The overall impact of zoning and land use regulations has been negligible to date, with conflicts being solved on a case-by-case basis. However, this impact is expected to grow as the number of solar installations increases and may become a significant deterrent to their general use if potential problems are not resolved. It is expected, however, that adequate planning coupled with legislation and public education (portraying STES as an energy saving technology) can alleviate most problems resulting from local regulations.

4. Solar Access Impacts

The "sun rights" issue or the problem of assuring continued access to sunlight on solar collectors or heliostats represents a potential social impact of STES development. If continued access to sunlight is in doubt, potential STES users, investors, and institutional decision-makers may be hesitant to commit their resources to the new technology. Similarly, changing the present social framework to provide for sun guarantees could produce significant modifications in existing institutions and legal relationships. The sun rights problem has been addressed by many researchers, including the American Bar Foundation and individual legal experts.

Potential responses to the need for guaranteed access to sunlight vary from case-by-case legal actions to comprehensive zoning or other land use controls. Approaches used and their impact on social institutions and solar energy use will vary both in different situations and also with the urgency and magnitude of the problem as solar equipment becomes more and more widely available

and in use. In a study on solar rights law, attorneys Kraemer and Felt provide a set of guidelines for evaluating the impact of alternative solar rights mechanisms and choosing appropriate actions for specific situations.[15/] In this framework, solutions should:

- protect users from shadows;
- promote solar energy development and use;
- be politically acceptable at all levels, especially local;
- complement but not replace existing remedies such as covenants and easements;
- avoid additional direct expense;
- pragmatically solve specific problems arising in use, not broad hypothetical problems;
- minimize new bureaucratic structures and red tape;
- avoid litigation between neighbors;
- avoid unnecessary burdens to property owners and developers; and
- provide flexibility for changing technology.

Specific alternative mechanisms for ensuring access to sunlight are discussed below.

a. Covenants and Deed Restrictions

In this alternative, land-owners agree to observe certain restrictions on use of their land, such as foregoing structures or vegetation which would shadow their neighbors' solar collectors during peak sunlight hours. Covenants can be established during development, especially for large tracts, and may be incorporated into the title document or administered by a controlling body on a case-by-case basis. However, convenants affect only a small number of units at one time, so that they are unsuitable as a universal solution. Because covenants do not necessarily run with the land, they may also cease to apply or be subject to renegotiation when land changes hands.

b. Light and Air Easements

Easements for access to sunlight are similar to covenants and may be negotiated between neighbors on the basis of mutual agreement or financial remuneration. An easement forbidding shading would be a negative rather than a positive agreement and thus by law it must be created by express grant on a case-by-case basis rather than by implication or prescription. The format of such agreements may be prescribed by law in some cases (e.g., in Colorado). In general, obtaining easements for sunlight may be a costly, time-consuming, and uncertain process, particularly where neighbors have esthetic objections or wish to protect future landscaping or development options. Consequently, their usefulness is limited as a general solution to the sun rights problem, and the necessity of obtaining such an agreement may act as a disincentive to potential STES users.

c. Private Nuisance Actions

Private nuisance actions based on shading traditionally have not been successful in the United States. Actions based on the English common law "Doctrine of Ancient Lights," which stated that an owner had a right to light falling across his neighbor's property if he had enjoyed its use for a period of 40 years, have been interpreted as unsuitable in America, where rapid change and development have been prime characteristics of national life.[12/] Private nuisance actions must instead demonstrate that collector shading results from malice and ill will and/or constitutes irreparable action causing greater harm than that expected from enjoining the defendant's activity, criteria which will be difficult to satisfy in many cases.[15,16/] In general, private nuisance actions have doubtful value as a solar protection. The right to free use and development of property is generally given high value in the United States, while solar nuisance suits would promote litigation between neighbors, burden owners and users, increase direct expenses, and provide at best only a case-by-case solution to collector shading problems.

d. Eminent Domain

Federal, State, and local governments have the power to authorize the taking of property for public use, and several researchers have suggested that the government might have the power to condemn airspace for sale or lease to STES users using eminent domain powers. There is some question whether such taking would be for a legitimate public use, as the immediate benefit would go to private users despite the ultimate impact on national energy and environmental resources; however, there is some precedent for such a broad interpretation, particularly in the development of the urban renewal concept. Questions of interpretation aside, this approach would have several undesirable impacts in that extensive bureaucratic action is required, complex mechanisms for determining the dollar value of condemned airspace must be developed, and the requirement of public use as opposed to mere benefit would require that collectors or heliostats actually be installed at condemned locations. Consequently, condemnation would provide for specific solar installations but would not provide for a general right to use sunlight if desired.

At the same time, owners and developers would be unduly blocked from using all lands in a condemned tract, even though many areas would not block potential collector sites. Enforcement of condemnation proceedings would tend to cause litigation between neighbors and require establishment of regulations which could be politically unacceptable to local officials.

A final impact of this approach would be the heavy involvement of government in crucial decisions about STES size, characteristics, and location, thereby weakening independent development of solar total energy systems by private industries and individuals.

e. Zoning and Land Use Control

"Three-dimensional zoning," or extension of zoning regulations to include control of shading on others' property, has been proposed as a prospective impact of widespread solar energy development. Such plans might provide for controls on allowable shading at critical periods, with variance procedures to prevent undue hardships. Some zoning plans already include provisions for adequate light and air (Colorado). Other zoning analogs would include height controls and esthetic zoning for historic districts. Crucial requirements for sunlight zoning controls would be the demonstration of public as opposed to private benefits, clear and specific wording of regulations, and equal and uniform application of restrictions within each zone.[15/] Drawbacks to such regulations would include vulnerability to challenge as an undue burden on property owners and the need for complex administrative structures. Much litigation would probably be generated. Sunlight zoning would be likely to raise severe political opposition on the basis of limitations on the free use and development of land. Several researchers have suggested using transferable development rights or density bonuses, compensating developers who are prevented from free use of land at some locations by allowing wider land uses or greater density at others.

Despite their drawbacks, zoning controls may be a significant element in determining the ultimate impact of solar energy. Comprehensive zoning plans may provide a framework to accommodate the increasing trend of enlarging public benefit concepts to include energy and environmental considerations. As solar total energy system use reaches significant proportions in specific localities, local zoning actions may be a useful mechanism for providing access to sunlight.

Subdivision requirements are land use controls similar to zoning rules which are imposed on developers of large tracts by local government to compensate for community growth. Typical pro-

visions are for open space, schools, roads, and sanitary facilities. These requirements might be enlarged to include provisions for STES capabilities and shade protections. Although subdivision requirements tend to be more flexible than zoning laws, they are similarly prospective and local in nature.

5. Public Nuisance Actions

Public nuisance regulations are based on the police powers of State and local government and most State criminal codes define specific acts of public nuisance and provide for their abatement. A public nuisance is generally defined as the "doing of or the failure to do something that injuriously affects the safety, health, or morals of the public or causes hurt, inconvenience, or damage to the public generally."[15/] Kraemer and Felt feel that public nuisance law represents the best and simplest way to protect solar collectors from shading by other property uses. Protection of solar energy use would preserve the community by providing energy alternatives and reducing dependence on scarce or environmentally damaging fuels. Unlike zoning, public nuisance regulations are also less vulnerable to constitutional challenge on the basis of undue taking of property or equal justice and due process provisions. Only structures which actually created shading problems would be affected. Finally, expanded bureaucratic processes or public court actions would be minimized.

Kraemer and Felt provide a model solar law defining shadows on a solar collector as a public nuisance and specifying applicable equipment, times of day, and sources of shadow. A municipal ordinance similar to Kraemer and Felt's proposed law is presently under study by the City of Virginia Beach, Virginia.[17/] This ordinance forbids shading of public beaches on the Atlantic Ocean or Chesapeake Bay during peak periods of sunlight and recreational use. Although this ordinance was designed to protect recreational values, it is being observed by many solar enthusiasts as a potential model for solar collector protection as well.

In summary, most sources consulted have not encountered significant conflict between solar technology use and the existing social infrastructure. However, more conflicts are foreseen as solar use becomes more widespread. While solar total energy systems are relatively rare, case-by-case solutions such as covenants and easements or private nuisance actions would be the most prominent social impacts. Broader measures such as zoning and public nuisance regulations may evolve as the number of STES installations and potential conflicts increase. Meanwhile, such impacts must be addressed in order to minimize their action as disincentives to long term solar development and planning.

Most authorities agree that the greatest institutional impacts of solar energy development will occur at the local level. Consequently, the amount and quality of information on solar technologies and their social implications will continue to be a crucial factor in determining social impacts. Public education at the community level could do much to remove potential social and institutional barriers to solar total energy system deployment.

SECTION V

NEPA DOCUMENT WORK PLAN AND
ENVIRONMENTAL RESEARCH PROJECTS

A. Introduction

The purpose of this section is to lay out a preliminary draft work plan for environmental analysis of the solar total energy system concepts under development by the Energy Research and Development Administration. It addresses the preparation of Environmental Development Plans, Environmental Impact Assessments, and Environmental Impact Statements as well as the conduct of basic and applied research supportive of developing a better understanding of the environmental attributes of STES.

The work scheduled in this report should not be construed as official plans of either the Division of Solar Energy or of ERDA as a whole. The work shown is that identified by the contractor. Many of the projects identified and outlined in Section D can be carried outside of ERDA and can be handled in a variety of ways. The scheduled work does not take into account breakthroughs or findings which may result in the need for reductions or expansions in effort and it may not reflect specific work already underway in the public or private sectors.

B. Description of NEPA Documents

1. Background

The National Environmental Policy Act of 1969 (NEPA) implemented by Executive Order on March 5, 1970, and the guidelines of the Council on Environmental Quality of August 1, 1973, require that all agencies of the Federal government prepare detailed environmental statements on major Federal actions significantly

affecting the quality of the human environment. The objective of NEPA is to build into the Federal agency decision-making process, at the earliest possible point, an appropriate and careful consideration of all environmental aspects of a proposed action in order that adverse environmental effects may be avoided or minimized.

In carrying out this mandate, each agency of the government has set out a policy and procedures for implementing these requirements. ERDA currently operates under official guidelines originally established by and for the now defunct Atomic Energy Commission. In an effort to up-date and reorient the guidelines to meet ERDA's need, alternative guidelines are now being prepared within ERDA.

Although the proposed revisions have yet to be finalized or adopted, because the proposed changes are so extensive and this document is to serve as an input to a future agency planning effort, for purposes of this analysis the most recent proposed revision (November 1, 1976) has been used to represent the future official guidelines. The discussion of NEPA report requirements and recommended work schedule is predicated on the guidance provided in the November 1 draft revision.

The backbone of ERDA's NEPA compliance program is the preparation and review (by the agency and the public) of documents addressing the environmental aspects of programs and projects of the agency. Three types of documents are particularly important. These are Environmental Development Plans (EDP's), Environmental Impact Assessments (EIA's), and Environmental Impact Statements (EIS's). Each is described below.

2. Environmental Development Plans

An Environmental Development Plan (EDP) is the basic ERDA management document for the planning, budgeting, managing, and reviewing of the broad environmental implications for each energy

technology alternative for each major ERDA research, development, and demonstration and commercialization program. The EDP is designed to identify environmental issues, problems, and concerns as early as possible during the program's development; to analyze the available data and assess the current state of knowledge related to each issue, problem and concern; to set forth strategies to resolve these; to set forth the processes by which the public is involved in identification and resolution of these issues, problems, and concerns; and to designate significant milestones for resolution of these issues, problems, and concerns. The timing of the EDP's milestones reflect the sequencing of the technology development. The EDP's, once completed, are made available to the public.

3. Environmental Impact Assessments

An Environmental Impact Assessment (EIA) is a written report prepared by an Assistant Administrator or an ERDA program office, which evaluates the environmental impacts of proposed ERDA actions to assure that environmental values are considered at the earliest meaningful point in the decision-making process. Based upon this evaluation, ERDA determines whether or not an environmental impact statement should be prepared. The EIA is intended to be a brief, factual, and objective document describing the proposed action; the environment which may be impacted; the potential environmental impacts during construction, operations, and site restoration; potential conflicts with Federal, State, regional, or local plans; and the environmental implications of alternatives.

4. Environmental Impact Statements

An Environmental Impact Statement (EIS) is a document prepared at the earliest meaningful point in the decision-making process

which analyzes the anticipated environmental impacts of proposed ERDA actions and of reasonably available alternatives. It reflects responsible public and governmental views and concerns. EIS's are prepared in response to plans in the program EDP or after the review of an EIA which identifies potentially significant impacts. The EIS goes through a specific preparation process involving agency and public review.

The EIS goes through four steps during its preparation. The preliminary draft is reviewed within ERDA; the draft is distributed to the public for review and comment; the preliminary final, incorporating comments submitted to ERDA in response to the draft, is reviewed within ERDA; and the final EIS is issued reflecting the agency's final review and deliberations. This final EIS is then officially filed with the Council on Environmental Quality and distributed to the public. Except in special cases, no ERDA action subject to EIS preparation can be taken sooner than 30 days after the final EIS has been issued.

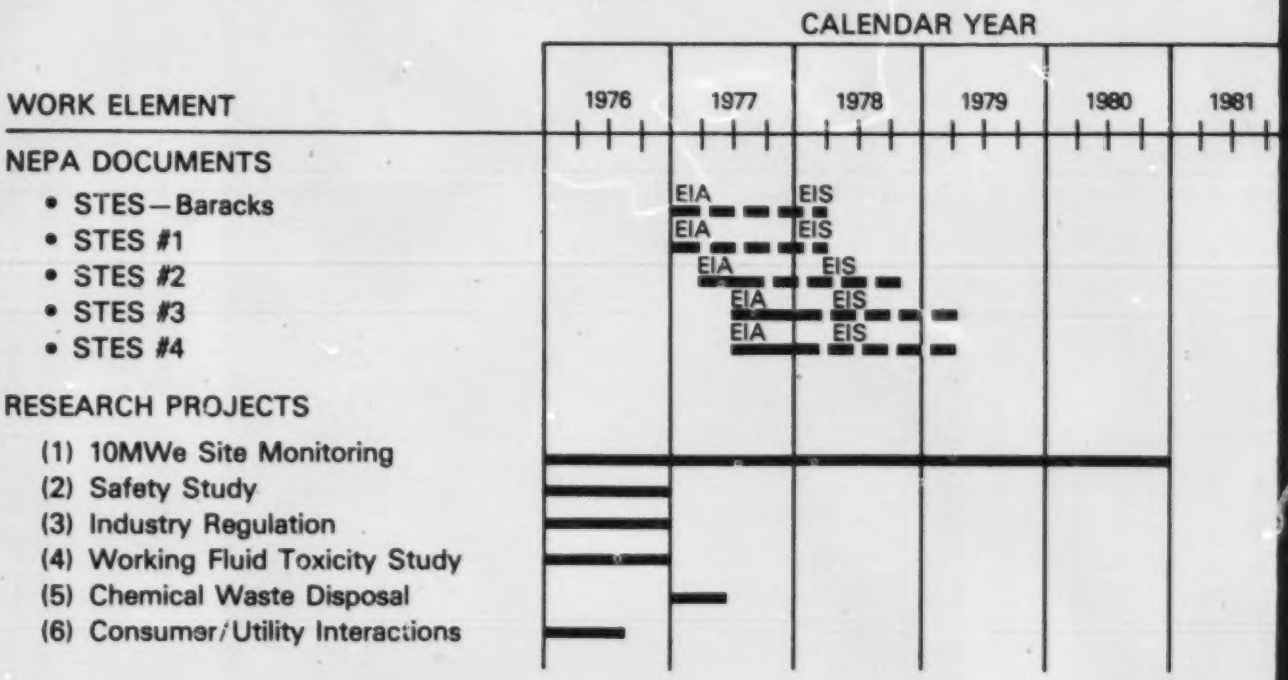
EIS's can be prepared covering programs, projects, or the use of ERDA facilities. In each case the document must reflect the utilization of a systematic interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts.

The report includes a description of the existing envionment and a description and environmental analysis of the proposed action and its alternatives, including an analysis of resource requirements and land use implications. There is a specific review of the unavoidable adverse environmental effects and a comparison of the advantages and disadvantages of the proposed action and it alternatives.

C. NEPA Document Work Plan

Figure V-1 presents an environmental work schedule for various solar total energy system projects. Also included is a schedule for various research projects which are proposed below.

FIGURE V-1
SOLAR TOTAL ENERGY SYSTEM ENVIRONMENTAL WORK SCHEDULE



D. Research and Development Projects

Through the preparation of EEA's environmental survey of the ERDA solar total energy system program, a wide range of environmental issues were identified which could not be adequately analyzed within the context of this study due to the complexity of the problems, the general lack of necessary research data, and the level of effort and schedule of the EEA study. This section identifies specific follow-up research projects which the EEA staff felt were critical to the understanding of the environmental consequences of large scale deployment of solar total energy systems and which are not likely to be specifically or adequately addressed solely in the preparation of NEPA documents. Many other research projects were identified during EEA's study. This list represents a condensation and trimming down of draft lists to those projects which are felt to be of greatest importance to the advancement of solar total energy system use and the associated decision-making process within the Federal government.

1. On-Site Monitoring of Climatological and Ecological Parameters at the 10 MWe Solar Thermal Electric Pilot Plant

- Prior to operation of the 10 MWe facility, monitoring shall take place to characterize the physical/chemical characteristics of soil and groundwater at the site. Local flora and fauna shall also be characterized at the site and an adjacent "similar" site.

- During operation of the facility these parameters shall be intermittently re-evaluated to determine the net impact of heliostat emplacement and operation on the rate and extent of change in soil conditions, post construction flora and fauna repopulation, water balance at the soil/air interface, and potential climatological perturbations.

2. Safety Procedures for Fabrication, Transport, Construction, and Operation of Heliostats and Distributed Collectors

- Develop control measures (hardware and/or operational) which will minimize or alleviate hazards due to misdirected light reflected by heliostats and collectors during all phases of their fabrication and use.

- Assess the cost and effectiveness of specific safety procedures which might be applied to residential and commercial solar thermal electric facilities.

- Develop a training program and handbook to be used in preparing workers and operators who will deal with the use and handling of heliostats.

3. Regulation of the Solar Industries

As the various solar technologies move into large scale commercialization, responsibility for insurance of equipment dependability, efficency, durability, and safety will fall both on the government and the industry. This study would:

- Identify the current mechanism of governmental or private regulation of the solar technolcgy industries and their conventional technology counterpart(s).

- Assess the adequacy of current and future regulatory mechanisms, in particular, the extent to which self-regulation is likely and will be adequate.

- Develop and analyze alternative regulatory options available to government (Federal, State, local) and industry (through associations) to insure the quality of solar technology products and to determine legal liability precedents and the impact on the insurance industry.

4. Liquid Working Fluid Additives Toxicity/Contamination Analysis

- Survey all working fluid additives to identify chemical composition, range of concentrations likely to be found in water based working fluid, and reason for using additive.

- Analyze various paths for entry of working fluid into the individual domestic water supply and estimate possible concentrations in the drinking water supply.

- Review effects information to determine type of effect severity of single or multiple doses incurred prior to detection of the leak (due to water taste or system failure).

- For those contaminants which present a risk, evaluate control strategies which might include:

  -- taste or color indicator of a leak;

-- a leak detection system; and or

-- redesign to prevent leaks from occuring; and/or

-- elimination of additive or use of an alternative additive.

5. Solid and Liquid Waste Dispcsal

- Analyze alternative methods for treatment and disposal of used storage salts and working fluid removed from STES systems during maintenance or repair.

- For each approach estimate cost, labor requirements, and net environmental impact, and determine whether regulations of financial incentives will be needed to insure adequate implementation.

6. Consumer/Utility Relations

- Analyze the shift in electricity demand which can result from solar total energy system use.

- Determine the impact this shift will have on utility industry capital requirements and operating costs.

- Identify alternative pricing mechanisms for distributing electricity generating costs to STES users and non-solar customers.

- Identify mechanisms avialable to the government to insure that pricing structures which are adopted do not place severe or unfair costs on a particular consumer group.

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